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(54) Diaphragm Pump

(57) A diaphragm pump e.g. for vacuum generation, includes a diaphragm (5) secured at its periphery (13) to the pump casing (2), and in its central region to the head (8) of a connecting rod (4), by means of a fastening plate (9). Between the regions where the diaphragm (5) is secured, is a free region (14) where it is subject only to bending stresses.

To avoid the substantial overlapping of bending and compressive stresses where the diaphragm (5) is secured, in at least one, and preferably both, of the regions there is provided a clamped region (A) where the diaphragm (5) is subjected to compressive stresses, and a guide region (B) between the clamped region (A) and free region (14) where flexure of the diaphragm (5) is restricted, but compressive stresses are substantially lower than in the clamped region (A), preferably being eliminated. Between the clamped region (A) and the guide region (B) there may be a transitional region (C) over which the compressive stresses decrease progressively.

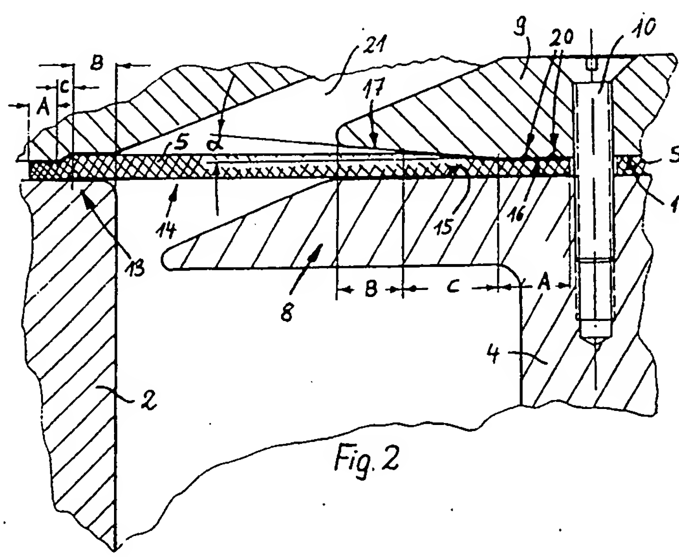

Fig. 2

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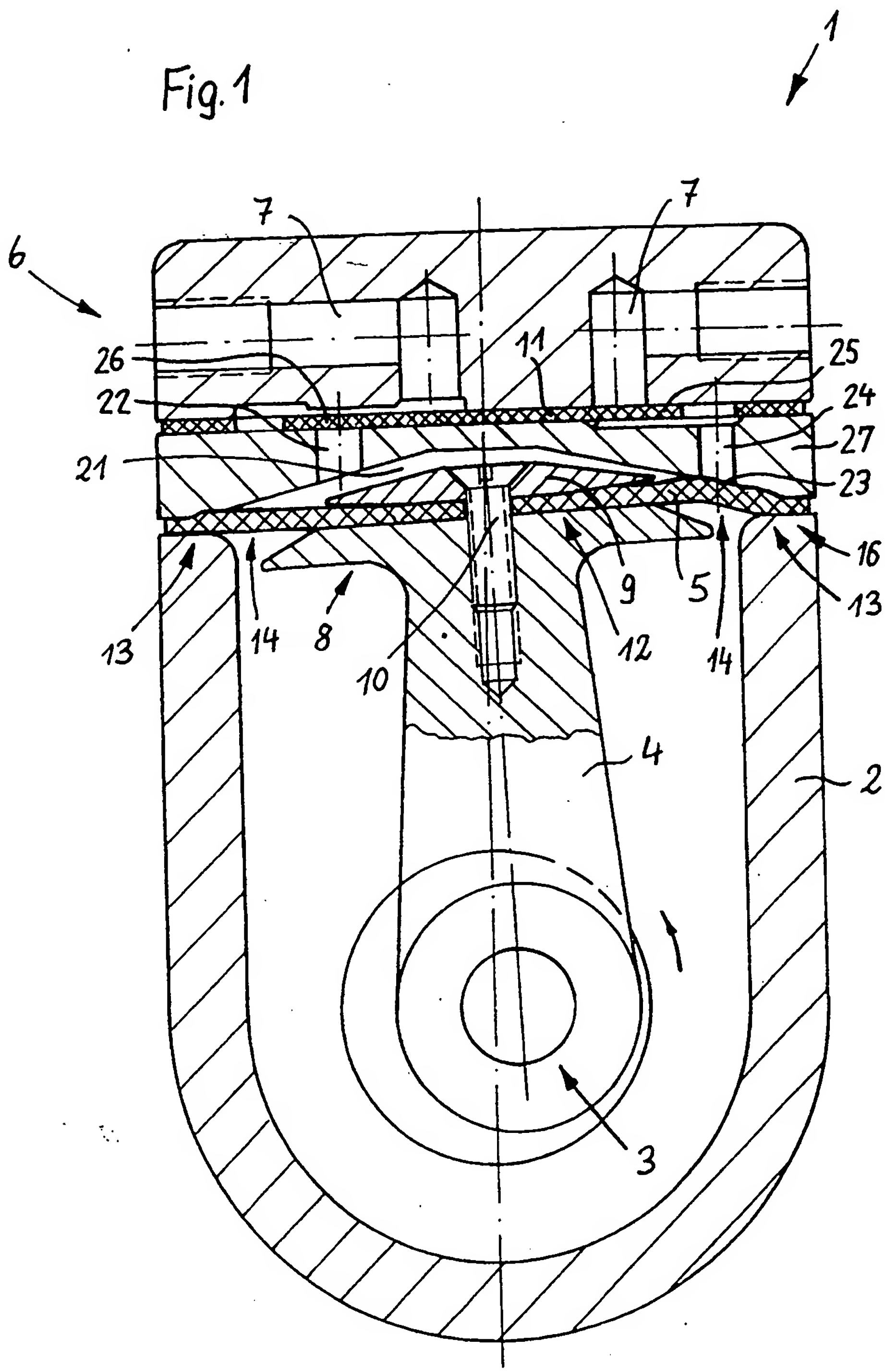
Fig. 1



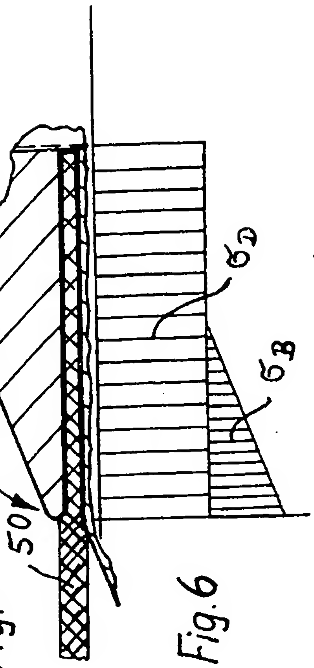


Fig.5

Fig.6

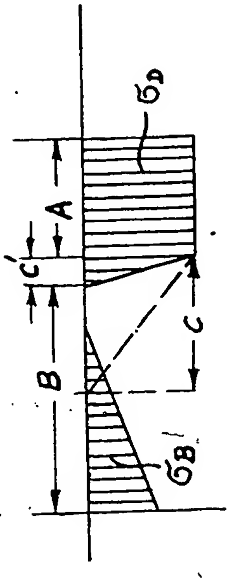


Fig. 4

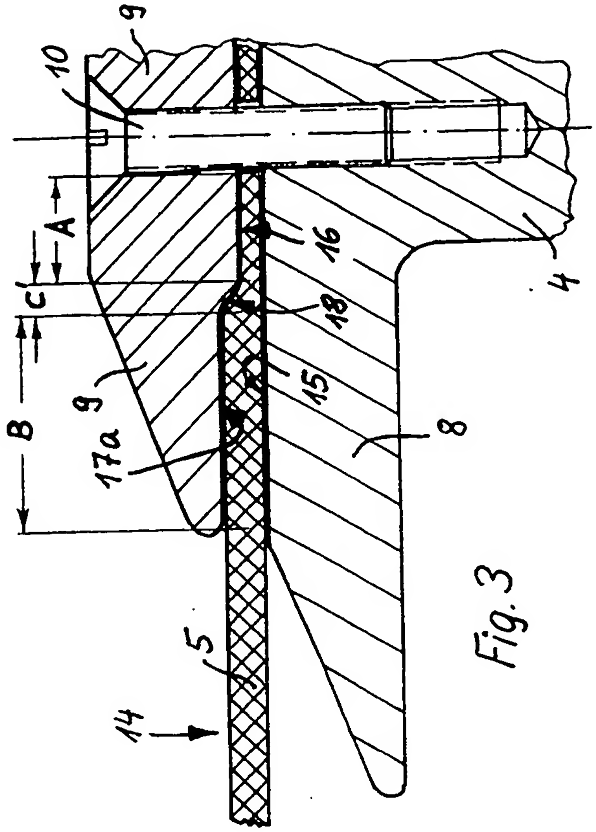


Fig. 3

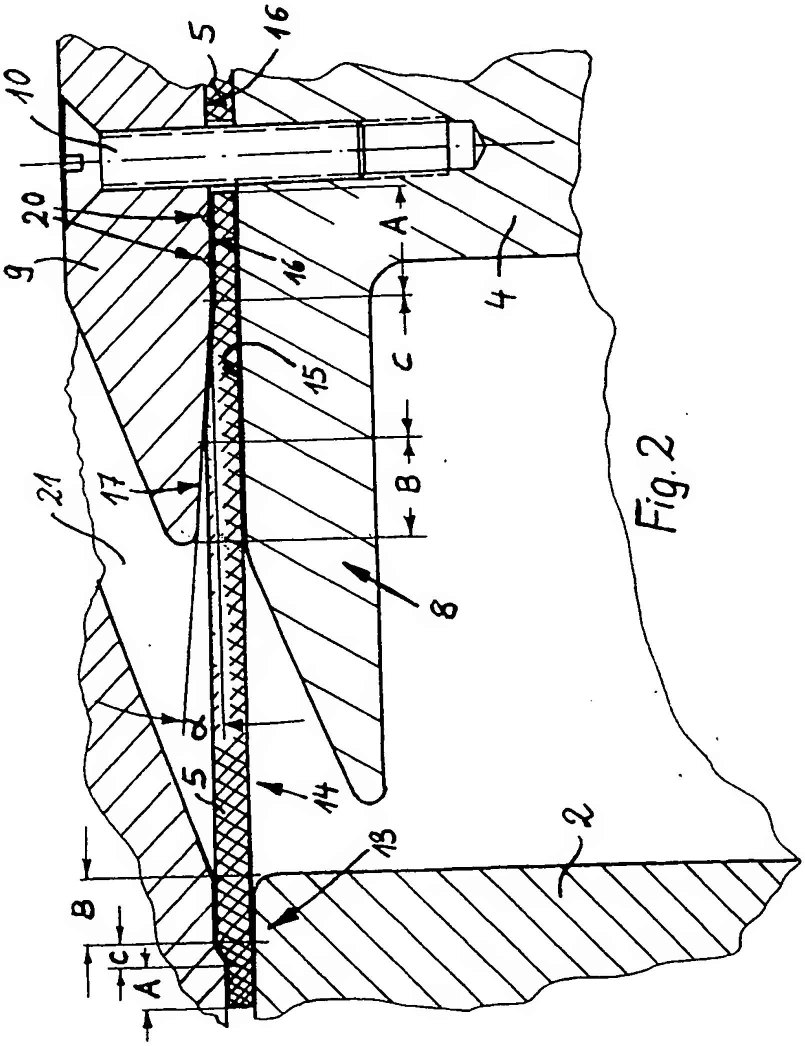


Fig. 2

SPECIFICATION
Diaphragm Pump

This invention relates to a diaphragm pump.

Such a pump may for example, comprise a flat diaphragm clamped in its central region and adjacent its periphery to a connecting rod and a pump casing respectively. The diaphragm may be planar when the connecting rod is in its central position. The diaphragm may be substantially free of stress at least in respect of its unclamped, free region. The diaphragm pump may have valves controlled by the pressure differences of the flow medium.

Diaphragm pumps have been used successfully for a long time, e.g. for vacuum or pressure generation, particularly in the case of gases or vapours. They still have, however, certain disadvantages inasmuch as the life of the diaphragms may be relatively short when currently available materials are employed. Replacement of the diaphragm then leads to standstill times for the pump, which does not enable the continuous operation which is desirable.

It has been found that the diaphragm experiences, generally, its greatest load at transitions between the clamped regions, where the diaphragm is compressed and its free, unclamped region where it is however subject to bending stresses. Especially with a comparatively notch-sensitive diaphragm material which may have to be used because of e.g. the chemical properties of the flow medium, such as its corrosiveness, frequently only a comparatively short trouble-free operation of the pump can be obtained.

According to the invention, there is provided a diaphragm pump including a diaphragm having a clamped region and a free region, wherein between the clamped and free regions there is a guide region in which means are provided to restrict flexure of the diaphragm but in which clamping forces on the diaphragm are substantially less than in the clamped region.

Preferably, in the guide region the diaphragm is substantially free from clamping forces.

By means of the invention, compressive and bending stresses need not occur at the same point on the diaphragm. This results in a substantially longer life of the diaphragm and consequently longer trouble-free operation of the pump.

Metering pumps are known, which have diaphragm clamping on both sides in a central region by means of conical bodies. These are, however, slowly running pumps primarily suitable for liquids and execute only a few revolutions per minute. Additionally, a specially shaped diaphragm is provided. Such pumps are unsuitable for vacuum generation and also do not pose the aforementioned problems.

A pump in accordance with the invention may advantageously be suited for vacuum generation and may for example have a speed in the range of approximately 1,500 to 3,600 revolutions per minute, preferably in the range 1,500 to 1,800 revolutions per minute. Such a vacuum pump may be constructed, as is known, so that the mouth of a feed pipe leading from a suction valve to the pumping chamber, may be closed by the diaphragm near its outer periphery, where it is first lifted by the connecting rod. The connecting rod may have, as is known, a mushroom-shaped profile to assist in pressing the diaphragm against the feed pipe mouth.

In a pump in accordance with the invention, preferably between the guide region and the clamped region there is a transitional region over which clamping forces on the diaphragm decrease progressively from the clamped region to the guide region.

Advantageously a said clamped region and its associated guide region are always provided in a central region of the diaphragm, where it is secured to the connecting rod. In this event, advantageously the diaphragm is secured between opposed surfaces on the connecting rod and a fastening member respectively, said opposed surfaces being substantially parallel in the clamped region, and the spacing between the surfaces being greater in the guide region than in the clamped region.

In one such arrangement the opposed surfaces diverge over the guide region. In another such arrangement the opposed surfaces are substantially parallel over the guide region and are spaced apart in said guide region by a distance substantially equal to the thickness of the diaphragm in an uncompressed state.

With this particular arrangement, preferably one of said opposed surfaces has a first planar portion over the clamped region and a second planar portion over the guide region, set back from said first portion, there being a curved portion interconnecting said first and second portions and defining a transitional region.

Preferably the one of said opposed surfaces which is on the connecting rod, is substantially planar, and the other surface, on the fastening member, is suitably contoured to provide the guide region, although the reverse is possible.

Although it is desirable that a guide region always be provided adjacent the central clamped region of the diaphgram, advantageously a guide region is also provided adjacent the region where the diaphragm is clamped adjacent its periphery to a casing for the pump. There are similar load conditions to those in the central region, and this arrangement has further advantages regarding the life of the diaphragm.

In an arrangement where the diaphragm is clamped between opposed surfaces on the connecting rod and a fastening member, e.g. a plate, means may be provided which assist retaining and/or sealing of the diaphragm. Such means could comprise an annular groove or ridge, or a plurality of such grooves or ridges, running concentrically.

Some preferred embodiments of the invention

will now be described by way of example and with reference to the accompanying drawings, in which:—

Fig. 1 is a longitudinal section through a diaphragm pump in accordance with the invention;

Fig. 2 is a portion of Fig. 1 to a larger scale;

Fig. 3 is a view showing an alternative embodiment of mounting the diaphragm in its central region;

Fig. 4 is a schematic stress diagram for the embodiments of Figs. 2 and 3;

Fig. 5 is a view showing the mounting of the diaphragm in a known arrangement; and

Fig. 6 is a schematic stress diagram for the arrangement of Fig. 5.

Referring now to the drawings, in Fig. 1 a diaphragm pump 1 has a casing 2 in which a crank assembly 3 drives a diaphragm 5 via a connecting rod 4. In a pump head 6 are provided valve passages or bores 7 which interact with a valve plate 11.

The diaphragm 5 is clamped at its central region to the connecting rod 4 and adjacent its outer edge to the pump casing 2. A head 8 of the connecting rod has an approximately mushroom-like form, and to this head a fastening plate 9 is connected by means of a centrally arranged screw 10. The inner, central region 12 of the diaphragm 5 is secured between the connecting-rod head 8 and the fastening plate 9 and the outer, peripheral region 13 of the diaphragm is fixed between casing parts. The connecting rod 4 with the diaphragm 5 is situated in the pump 1 shown in Figure 1 directly in a central stroke position.

Where the diaphragm is secured to the connecting rod 4 in the central region 12, and also in the outer peripheral region 13, in each case there is provided a clamped region A and a guide region B (see Figures 2 and 3). In the guide region B the diaphragm 5 is held substantially free of clamping pressure in comparison with the clamped region A. This prevents substantial compressive and bending stresses from occurring simultaneously at any point on the diaphragm 5, which results in a substantially longer life of diaphragm 5. The compressive stress is primarily brought about by the clamping force, while the bending stress is brought about mainly by the relative movement of the diaphragm in relation to its clamped points.

It has been shown that especially in the case of notch-sensitive diaphragm materials, by means of the invention the life of the diaphragm can be substantially prolonged in relation to known diaphragm pumps. Indeed, in the case of diaphragms of notch-sensitive material damage of the diaphragm has previously occurred after a comparatively short time. Practical tests have shown that diaphragms of plastomeric material, that is, material which is flexible, but has small elastic properties, have in a diaphragm pump in accordance with the invention, three to four times the life of those on known diaphragm pumps and occasionally even more. Also in the case of diaphragms of elastomeric material, that is, material having good elastic (rubber-elastic) properties, a multiple of the life of the diaphragm can be achieved in comparison with known diaphragm pumps.

Due to the guide region B adjoining the free region 14 of the diaphragm 5 the elastically deformable zone of the diaphragm 5 is also enlarged. With the same stroke and diameter ratios this results in lower stresses in the diaphragm, so that thereby, also, a longer life is achieved.

Figure 2 shows in greater detail one preferred embodiment of a diaphragm pump in accordance with the invention. Here, the connecting-rod head 8 has a planar face 15 extending radially of the connecting rod 4 and on which rests the central region of the diaphragm 5. The fastening plate 9 clamps the diaphragm 5 from the other side. It has a radially extending clamping force 16 which is adjacent its central fastening bore for the screw 10 and which runs approximately parallel to the face 15 of the connecting rod head. Adjoining the clamping face 16 outwardly is a guide face 17, which runs at an angle clamping face 16, and to the face 15 of the connecting-rod head 8, so that the spacing between faces 15 and 17 increases.

In this embodiment of Figure 2, there is formed simultaneously by the regular incline of the guide face 17, the guide region B and also an intermediate or transitional region C in which the compressive stresses decrease radially outwards, while the possible bending stresses increase. A continuous transition is thereby obtained, by which notch effects are avoided. In the guide region B the diaphragm 5 is completely free of clamping pressure.

The guide face, 17 which in this embodiment partly acts also as a transition face, runs at an angle α of approximately 2 to 8° to the clamping face 16. An angle α of approximately 5° has been found to be especially favourable.

A modified embodiment of the invention with a different diaphragm clamping arrangement is shown in Figure 3. Here, a guide face 17*a* of the fastening plate 9, defining guide region B, is approximately parallel to the clamping face 16 but is set back therefrom. Its spacing from the face 15 of the connecting-rod head 8 corresponds approximately to the thickness of the diaphragm 5 in its relaxed state so that the diaphragm is free from clamping pressure in region B. Here, also, a transition zone C′ is provided, which is formed by a convex rounded transition 18 between faces 17*a* and 16. The diaphragm is guided parallel in guide region B and any bending stress which occurs is practically abolished towards the transition zone C′.

The compressive or bending stresses which occur where the diaphragm 5 is secured are reproduced in schematic form in Figure 4. This diagram relates primarily to the embodiment according to Figure 3. It shows that within the clamped region A, compressive streses δ_D occur practically exclusively due to the compression of

the diaphragm 5. In the transition zone C′ this compressive stress δ_D diminishes towards zero. Within the guide region B bending stresses δ_B predominate, which are gradually abolished from the free region 14 to the transitional region C′. There arises therefore no overlapping of compressive stresses δ_D and bending stresses δ_B at any point on the diaphragm 5. Correspondingly, the loading of the diaphragm 5 is also comparatively small. The diagram of Figure 4 shows by means of a broken line, the gradual abolition of compressive stress within the transition region C of the embodiment according to Figure 2.

For the sake of illustration, Figure 5 shows the conventional clamping of a diaphragm 50 in a known pump. The associated diagram of Figure 6, clearly reveals the overlapping of compressive stresses δ_D and bending stresses δ_B which accumulate at the outer clamping edge 19 to form a stress peak. This region therefore constitutes also the most strongly loaded point of the diaphragm. In practice, this has been confirmed by ruptures of the diaphragm which has occurred at this point.

In a pump in accordance with the invention, the gripping of the diaphragm 5 in the clamped region A can be further assisted by e.g. concentrically running grooves 20, as shown in Figure 2. These also improve the sealing in this region. Diaphragms of elastomeric material "migrate" into the grooves 20 in this region due to the clamping pressure, while with plastomeric materials this takes place owing to their flow behaviour, a short time after the compressive stress is applied.

For the clamped region A and for the guide region B or for the associated clamping face 16 and the guide face 17, 17*a* a ratio of their radial extension of between 1:1 and 1:2, preferably 1:1.5 is advantageous.

The diaphragm is preferably operated in a speed range of 1,500 to 1,800 revolutions per minute.

The above-described arrangements in accordance with the invention, for securing the diaphragm in its central region apply analogously also to the securing of the diaphragm 5 adjacent its outer peripheral region 13. This is shown in Figure 2, and it can be seen that there is a clamped region A, a transitional region C and a guide region B. The arrangement corresponds to that used for the central region in the embodiment of Figure 3.

In the embodiment of Figures 2 or 3, if necessary, the side of the fastening plate adjacent the diaphragm 5 can be made plane and extending approximately radially, the surface of the connecting-rod head 8 having a clamping face and a guide face. Furthermore, if required, it is conceivable also to have a symmetrical design in which both the fastening plate 9 and the upperside of the connecting-rod head 8 have in the guide zone B either a bevel or a set-back

It should also be mentioned that the stress conditions within the diaphragm securing regions allow a favourable cross-sectional profile of the fastening plate 9. Corresponding to the shape of the displacement compartment or pumping chamber 21, the fastening plate 9 has its greatest thickness and stability in the clamped region A, so that the desired high pressing forces can be transmitted effectively there. Also, owing to the above-mentioned conditions the fastening plate 9 as a whole can be kept comparatively thin, which is advantageous, amongst other things because of the desired low inertial forces.

Figure 1 illustrates clearly a special development of the diaphragm pump in accordance with the invention, if it is to be used for vacuum generation. A feed pipe 22 extends from a pressure valve 26 to the displacement compartment 21. This feed pipe is arranged at a point of an intermediate cover 27 for the displacement compartment 21, where in the case of known diaphragm pumps both the feed pipe from the pressure valve and the corresponding feed pipe from the suction valve are usually arranged. According to the present development, at least mouth 23 of the feed pipe 24 from the suction valve 25, in this embodiment the entire feed pipe 24 which leads from the suction valve 25 to the displacement compartment 21, is arranged in the plane of oscillation of the connecting rod near the outer clamped region 16 of the diaphragm 5, where this diaphragm is first lifted. Figure 1 clearly shows this position of the feed pipe 24 and its mouth 23. This mouth 23 is closed by the diaphragm 5 shortly after the beginning of the connecting-rod movement shown in Figure 1. The effect of this is that the increase of pressure in the displacement compartment 21 no longer has an effect on the space formed by the feed pipe 24 and the like. Thus, this space lying in front of the suction valve 25 is cut off as a clearance space. The achievement of this without additional expenditure is that the diaphragm 5 acts as an additional controlled valve on the suction side of the diaphragm pipe 1. Due to the fact that the connecting-rod head 8 has a mushroom-like profile in such a way that at the beginning of the displacement stroke it presses the diaphragm 5 against the mouth 23 of the feed pipe 24, this desired movement of the diaphragm 5 is assisted. The special arrangement of the mouth 23 of the feed pipe 24 for the suction valve 25, in conjunction with closure by the diaphragm 5, is known per se. However, together with the above-described design of the diaphragm pump, with clamped and guide regions adjacent the diaphragm periphery, the additional advantage is obtained, that the diaphragm is undamaged, e.g. also free from cracks, etc., for a very long time even in the region where it is intended to close the mouth 23. This is seen clearly at the outer marginal region 13 of the diaphragm 5, where the latter has its clamped region 16. Due to the more

to effect a good seal at the mouth 23 of the suction pipe 24 is also improved.

Claims

1. A diaphragm pump including a diaphragm having a clamped region and a free region, wherein between the clamped and free regions there is a guide region in which means are provided to restrict flexure of the diaphragm but in which clamping forces on the diaphragm are substantially less than in the clamped region.

2. A pump as claimed in claim 1, wherein between the guide region and the clamped region there is a transitional region over which clamping forces on the diaphragm decrease progressively from the clamped region to the guide region.

3. A pump as claimed in claim 1 or 2, wherein said clamped region is a central region of the diaphragm, where it is secured to a connecting rod.

4. A pump as claimed in claim 3, wherein the diaphragm is secured between opposed surfaces on the connecting rod and a fastening member respectively, said opposed surfaces being substantially parallel in the clamped region, and the spacing between the surfaces being greater in the guide region than in the clamped region.

5. A pump as claimed in claim 4, wherein said opposed surfaces diverge over the guide region.

6. A pump as claimed in claim 5, wherein the angle of divergence is between 2 and 8 degrees.

7. A pump as claimed in claim 6, wherein the angle of divergence is 5 degrees.

8. A pump as claimed in claim 4, wherein said opposed surfaces are substantially parallel over the guide region, and are spaced apart, in said guide region, by a distance substantially equal to the thickness of the diaphragm in an uncompressed state.

9. A pump as claimed in claims 2 and 8 wherein one of said opposed surfaces has a first planar portion over the clamped region and a second planar portion over the guide region, set back from said first portion, there being a curved portion interconnecting said first and second portions and defining said transitional region.

10. A pump as claimed in any of claims 4 to 9 wherein the one of said opposed surfaces which is on the connecting rod, is substantially planar, and the other surface, on the fastening member, is suitably contoured to provide the guide region.

11. A pump is claimed in any of claims 4 to 10 wherein a said guide region is further provided adjacent the region where the diaphragm is clamped adjacent its periphery to a casing for the pump.

12. A pump as claimed in any preceding claim wherein the ratio of the radial extent of the clamped region to that of the guide region is in the range of 1:1 to 1:2.

13. A pump as claimed in claim 12 wherein said ratio is 1:1.5.

14. A pump as claimed in any preceding claim, wherein in the guide region the diaphragm is substantially free from clamping forces.

15. A pump as claimed in claim 4, wherein one and/or the other of said opposed surfaces, in the clamped region, is provided with means for assisting retaining and sealing of the diaphragm.

16. A pump as claimed in claim 15, wherein the means for assisting retaining or sealing of the diaphragm comprises one or more annular grooves or ridges.

17. A pump as claimed in any preceding claim wherein a feed pipe leading to the pumping chamber may be closed by the diaphragm near its outer periphery.

18. A diaphragm pump substantially as hereinbefore described, with reference to Figs. 1 and 2 of the accompanying darwings, or as modified with reference to Fig. 3.

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